

**A MINIATURE REACTION CHAMBER TEMPLATE
STRUCTURE FOR FABRICATION OF NANOSCALE
MOLECULAR SYSTEMS AND DEVICES**

FIELD OF INVENTION

[0001] This invention relates to molecular systems and devices and, more particularly, to a unique micro-miniature reaction chamber template structure utilized to fabricate such devices.

BACKGROUND OF THE INVENTION

[0002] As one can ascertain, conventional electronics have fundamental limitations in regard to size, speed and so on. Many prominent scientific centers are working on utilizing molecules to provide an alternative for electronic processors. The use of molecules will result, obviously, in extremely small structures, which theoretically are capable of high operating speeds. Thus, the term molecular transistor has been utilized. In regard to such techniques, many centers have been utilizing gallium arsenide, as well as aluminum gallium arsenide with contacts with molecules disposed on the surface of such devices. Essentially, they are using new molecules and old semiconductor devices to try to produce new components. Thus, such researchers have proposed a molecular field effect transistor designated as MOLSET. This is basically a molecular tripod where the molecules form gate, source and drain electrodes with extremely small dimensions such as a spacing of 35 Angstroms between the source and drain and between the source and gate.

[0003] The art is in its infancy, as one can ascertain. For example, see an article in the *New York Times*, January 1, 2002 entitled, "Scientists Find that Tiny Pipes Offer Big Payoffs". This article discusses new technology known as microfluidics. This technology then utilizes silicon tubes, which are used to pump fluid in various directions and essentially operate like valves and so on.

[0004] It is an objective to provide a unique micro-miniature template structure for the fabrication of nanoscale molecular systems and devices.

SUMMARY OF INVENTION

[0005] The structure contemplated is composed of multiple layers of silicon, which are either doped or intrinsic, Pyrex and various metals. Silicon may or may not be totally or partially covered with silicon dioxide. The Pyrex is chosen to be suitable for field assisted bonding to silicon and the various metal layers are selected for their adherence to silicon or Pyrex, as well as their conductivity and chemical reactivity.

[0006] The basic structure is made to contain a number of tubes or fluidic pipes of varying cross sections in which a portion of the cross section is formed in the silicon and a second portion of the cross section may be formed in the Pyrex. It is also within the scope of this invention to form the cross section in two pieces of silicon separated by a thin layer of Pyrex. In any event, the use of field assisted bond between silicon and Pyrex makes the use of sodium ion transport in the Pyrex during the bonding process and it is possible by shaping the Pyrex layer to leave internal conductive paths. It is also possible to leave in the Pyrex oxygen

ions at the surface that were previously linked to the sodium ions, but can now be exposed for attachment to various organic molecules.

[0007] The use of various planes of the silicon structure makes it possible to obtain cavities of differing shapes during etching depending on the crystallographic orientation of the chosen planes. In addition, the extent of etching can also be controlled by the use of degenerately doped silicon layers and the conductivity selective etch. Moreover, the use of a particular crystallographic plane makes possible the construction of sharp edges for a localized high electric field. It is clear that specific areas of the silicon can be chosen to have dangling bonds to promote localized reactions enabling a nanostructure to form in a specific spot within the reaction chamber. Such localized reaction areas may also be formed using various layers of metal on either the silicon or the glass structure. In addition, the various fluidic pipes can also be formed if so desired at right angles to the main fluidic pipes enabling the injection of liquids at varying places within the reaction chamber structure.

[0008] If the field assisted bonding is performed in either a vacuum (or an inert atmosphere), the dangling oxygen bonds are exposed after the two layers are joined. After the voltage is lowered and the temperature is reduced to room ambient, various fluids can be introduced through the right angle conduit and allowed to reach the dangling oxygen bonds (or other localized metal surfaces) to allow the reaction to proceed at the desired places. Reaction of an appropriate voltage can also (by means of the highly localized electric fluid) cause the reaction to terminate at the junction.

BRIEF DESCRIPTION OF THE FIGURES

[0009] Figure 1 is an enlarged diagram in cross sectional view of a micro-miniature reaction chamber template according to this invention.

5 [0010] Figure 2 shows the template of Figure 1 utilizing micropipes.

[0011] Figure 3 is an extremely enlarged view of a vertical and horizontal array of micropipes forming an X-Y matrix to provide localized reaction sites at the cross points of the matrix.

[0012] Figure 4 consists of Figures 4A, 4B and 4C and basically shows a wafer of Pyrex which is eventually bonded to a wafer of silicon to form a composite structure as shown in Figure 4A.

[0013] Figure 5 consists of Figures 5A, 5B and 5C which basically shows a top wafer of silicon which is bonded to a bottom wafer of silicon coated with Pyrex to form a composite structure shown in Figure 5C. It is noted that in Figure 5 the co-apertures are rectangular in shape rather than circular as shown in Figure 4.

[0014] Figure 6 consists of Figures 6A, 6B and 6C and shows an alternate embodiment of a coated silicon wafer using vertical conduits to enable fluid placement.

20 [0015] Figure 7 consists of Figure 7A, 7B and 7C and again shows a top wafer of silicon bonded to a wafer of silicon which is coated with Pyrex having pipes or micropipes for enhancing reactions.

[0016] Figure 8 consists of 8A, 8B and 8C and basically shows a top wafer of silicon secured to a wafer of silicon coated with Pyrex and which has alternate channel configurations disposed throughout.

[0017] Figure 9 consists of 9A, 9B and 9C and basically shows a device according to this invention whereby the devices uses localized sharp pointed reaction areas disposed along the through channels to enable higher voltage reactions to occur at the tips of the pointed reaction areas.

DETAILED DESCRIPTION OF THE FIGURES

[0018] Referring to Figure 1, there is shown an example of a basic structure according to this invention. In Figure 1 a layer of silicon 11 is bonded to a layer of Pyrex glass 10, which in turn is bonded to another layer of silicon 12. The silicon is bonded to the Pyrex layer 10 by means of a field-assisted bond. The field-assisted bond is formed by applying pressure between the silicon and the Pyrex under the influence of a voltage, which causes the silicon molecules to migrate into the glass molecules, forming a strong bond. As one knows, Pyrex glass contains sodium and the use of Pyrex for layer 11 makes the use of sodium ion transport during the bonding process to bond to the silicon. One can also shape the Pyrex layer 10 so that one can form internal conducting paths. Thus, Figure 1 shows the two pieces of silicon 11 and 12 separated by a center portion, which is a thin layer of Pyrex 10.

[0019] Referring to Figure 2, there is shown the structure of Figure 1, which includes a top layer of silicon 21, a bottom layer of silicon 22 and a layer of Pyrex

20. In the layer of Pyrex 20 there is shown a plurality of microtubes as 30 and 31. These microtubes are formed by etching or other processing of the glass, which is well known. It is also understood that such microtubes can also be formed in the silicon by etching the similar products. The microtubes are pipes or channels between 1 to 10 mils in diameter and can be produced by active ion etching. In this manner, fluids containing molecules can be injected into the microtubes 30. It is also envisioned that there will be an X-Y matrix of microtubes whereby each of the microtubes form an X-Y grid and therefore fluids can be injected at any point in X-Y grid to enable a fluid to reach a cross point or a local area. At this local area, there would be a small spot or opening. At this spot, there would be dangling oxygen bonds. These dangling oxygen bonds are, of course, utilized to enable one now to couple organic molecule to the dangling oxygen bonds so as to utilize the structure shown in Figures 1 and 2 as a template for connecting organic molecules to the silicon structure. One can therefore produce organic devices, such as electronic devices or other conducting devices. The organic molecules that can be employed would be molecules like biphenyldithiol and biphenyldiamine, as well as diphenyls. Such compounds are soluble in alcohol and ether and are used in organic synthesis. Therefore, the fluids that can be used to transport these compounds are alcohol and ether as well as other solvents. In any event, the important aspect of the invention is that one utilizes Pyrex with various layers of silicon structures. The use of Pyrex enables the transport of sodium ions and Pyrex oxygen ions at the surface that were previously lined to

sodium ions are now exposed so they can be attached to various organic molecules.

[0020] Referring to Figure 3 there is shown an extremely enlarged view of a series of micropipes, which are formed in the Pyrex or the silicon. As we can see, there are micropipes 41, 42 and 45, which are oriented in the vertical direction with micropipes 43 and 44 oriented in the horizontal direction. The intersection between pipe 44 and pipe 45 creates a cross point 40, which is a localized area in the glass or silicon, where fluid can be introduced to the pipe. At the localized area, the molecule will exist and by the use of electric fields or other devices, one can now cause the migration of sodium ions and therefore produce oxygen ions which are dangling at that location. One can now attach a molecule for a specific spot on the silicon structure shown as Figures 1 and 2. It is understood that Figure 3 is an enlarged view and the matrix contains thousands of micropipes developed in the structures of Figure 1 and Figure 2.

[0021] Referring to Figure 5, which consists of Figure 5A, 5B and 5C, is shown an alternate embodiment of a micro-miniature reaction chamber template circuit according to this invention. Figure 5A shows a top wafer which is fabricated from silicon. The wafer 61 has rectangular channels or micropipes 62, 63 and 64 which are directed from one side of the wafer to the other side of the wafer. Figure 5B shows another silicon wafer 66, which is coated with Pyrex glass 65. The Pyrex glass 65 is bonded to or otherwise deposited on the silicon wafer 66 and has corresponding channels 64A, 63B and 62A. Figure 5C shows the top wafer of Figure 5A bonded to the Pyrex layer 65, thus having a silicon wafer

separated by a Pyrex layer 65 bonded to another silicon wafer 66. There are three channels or pipes 68, which are directed from one side to the other side, where each through channel can accommodate a fluid flow, as described above.

[0022] Referring to Figure 6, which consists of Figures 6A, 6B and 6C, there is shown in Figure 6A a top wafer 70 fabricated from silicon. The wafer 70 again has semi-rectangular channels 72, 73 and 74. Each channel is associated a plurality of vertical conduits, where the fluid can be introduced on the top of the channels, as well as through the pipes to be formed. Shown in Figure 6B is a wafer of silicon 75 coated with a layer of Pyrex 76 and having corresponding channel 74A, 73A and 72A. Figure 6C shows the top wafer 70 secured to the bottom wafer 75 at the Pyrex layer by an electro-assisted bond. As one can see a molecule containing fluid can be introduced through the vertical conduits 71 to flow into the pipes 76 as shown in Figure 6C.

[0023] Referring to Figure 7 which consists of Figures 7A, 7B and 7C, there is shown a top wafer 80 of silicon having semicircular apertures 84, 85 and 86 directed from one side of the wafer to the other side of the wafer. Figure 7B shows a bottom wafer of silicon 83 which is covered with a layer of Pyrex 82 which is deposited on the silicon. The silicon wafer 83 depressions 86A, 85A and 84A, which are aligned with depressions 84, 85 and 86. The top wafer 80 is bonded to Pyrex layer 82 which is bonded to silicon layer 83 to form the structure shown in Figure 7C. The through holes 88 or pipes are formed as above.

[0024] Referring to Figure 8, which consists of Figures 8A, 8B and 8C, there is shown again a wafer of silicon 90. In this instance there are channels 91, 92 and

93, which channels are not through channels, with the exception, for example, of channel 93, but provide areas in which an organic fluid can flow. Figure 8B shows a bottom wafer of silicon 97 coated with Pyrex glass to form corresponding channels 91A, 92A and 93A. Figure 8C shows the top wafer 90 joined to the bottom wafer 91 via the Pyrex layer 95. It is seen from Figure 8 that all the channels are not through channels, but are channels which are used to circulate fluid in any desired manner through the structure. However, there is a through path from one end to the other as from 91A and 92A to 93A.

[0025] Referring to Figure 9 which consists of Figure 9A, 9B and 9C, there is shown in Figure 9A a silicon wafer 116 having through channels 104, 105 and 106. Shown in Figure 9B is another silicon wafer 110 having a Pyrex layer deposited thereon. The silicon wafer 110 has corresponding channels 104A, 105A and 106A. Each channel has localized high field reaction areas designated by 102 and 103. These high field reaction areas are basically points which are tips which are directed along the apertures as 106 and 104, and which will produce high electric fields where the voltage is applied between the silicon and Pyrex between the wafer. These high electric fields which are produced at the tips will enable the efficient reaction areas to occur at the localized tip areas, plus each of the tips as 102 and 103 terminates in a sharp point. As one can understand, when a voltage is applied between the chips, the sharp points will basically create high voltage fields, which are localized and whereby reactions can take place as indicated above.

[0026] It is also understood that localized reaction areas may also be formed using layers of metal under the silicon or the glass structure. The layers of metal can be, for example, layers of aluminum, gold, and so on. These metal layers can also be formed into pipes, and therefore provide reaction areas.